Ecosystem Change and Climate Feedback Under Greenhouse Gas Increase and Thermohaline Circulation Collapse

Paul A.T. Higgins & Stephen H. Schneider

Department of Biological Sciences, Stanford University

Introduction

Some climate models now show thermohaline circulation (THC) collapse due to increasing greenhouse gas (GHG) concentrations (Schneider and Thompson, 2000, Rahmstorf and Ganopolski, 1999, Wood et al., 1999), suggesting multiple equilibria exist for THC (Ganopolski and Rahmstorf, Submitted). Substantial differences in climate are possible as a consequence of transitions between equilibria (Wood et al., 1999, Rahmstorf and Ganopolski, 1999, Vellinga and Wood, In press).

The potential for THC collapse has received considerable attention from physical scientists, but almost none from the biological science community. Social scientists have also begun to examine the effect that THC collapse could have on social and economic well being (Keller et al., 2000, Mastrandrea and Schneider, 2001). These attempts to quantify social and economic damage do not consider biological responses, however, and THC collapse could have dramatic impacts on ecosystems.

Ecosystem responses could alter the flow of goods and services and create feedbacks to the climate system through alteration of albedo, carbon storage, and the hydrological cycle. Therefore, the resulting abrupt and variable climate changes could cause reverberations throughout the climate system and affect the quality of human life over many centuries after the THC alteration was initiated.

Table 1. Temperature and carbon dioxide for each scenario

Scenario	DJF	MAM	JJA	SON	CO2
Control	Historical	Historical	Historical	Historical	350
Warming	+5	+5	+5	+5	1200
Cold DJF	-6	Historical	Historical	Historical	395
Cold Year	-6	-6	-6	-6	395

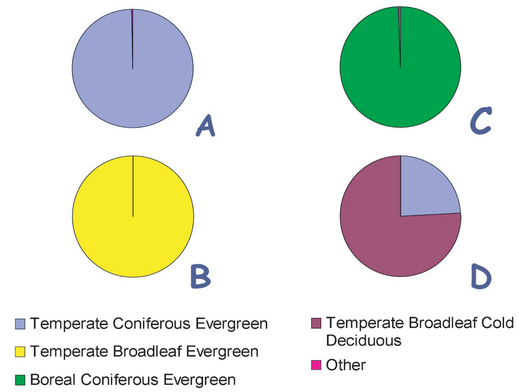

Figure1. Dominant plant functional types under (A) control, (B) warming, (C) cold year, and (D) cold DJF scenarios

Methods

We generated equilibrium temperature scenarios for Central England (Table 1) by interpolating results from a climate model of intermediate complexity (CLIMBER-2). These scenarios force IBIS, a DGVM capable of simulating changes in ecosystem structure and function through time. A sub-set of scenarios include 1) a climate control consisting of historical climate as measured in the long term Central England temperature (CET) record, 2) a warming simulation (+5º relative to CET) in which THC remains active, 3) THC collapse scenario in which monthly temperatures decline by 6º throughout the entire year, and 4) THC collapse scenario in which winter temperatures decline 6º but CET temperatures are used throughout the remainder of the year.

References:

Ganopolski A, Rahmstorf S (Submitted). Physics Review Letters.

Higgins PAT, Mastrandrea MD, Schneider SH (In press). Philosophical Transactions of the Royal Society of London, 357.

Keller K, Bolker BM, Bradford DF (2000) In Yale/NBER/IIASA workshop on potential catastrophic impacts of climate change Snowmass, CO.

Mastrandrea M, Schneider S (In press). Climate Policy.

Rahmstorf S, Ganopolski A (1999). Climatic Change, 43, 353-367.

Schneider SH, Thompson SL (2000). In: New Directions in the Economics and Integrated Assessment of Global Climate Change (eds, DeCanio SJ, Howarth RB, Sanstad AH, Schneider SH, Thompson SL), pp. 59-80. The Pew Center on Global Climate Change, Washington, D.C.

Vellinga M, Wood RA (In press). Climatic Change.

Wood RA, Keen AB, Mitchell JFB, Gregory JM (1999). Nature, 399, 572-575.

Results

Dominant plant functional type (PFT) varies among the four scenarios with temperate evergreen conifers in the control, temperate evergreen broadleaved vegetation in the warming scenario (a PFT not present in the control), boreal confers in the annually cooled THC collapse scenario (a PFT typical of Scandinavia), and a mix of temperate evergreen conifers and broadleaved deciduous vegetation in the winter only THC collapse scenario (figure 1).

Annual average leaf area index (LAI-figure2) more than doubles in the warming scenario relative to the control (11.04 versus 5.12). Similarly, the increase in winter leaf drop that occurs in the winter cooling scenario causes a seasonal decrease in LAI from 5.1 in the control to 1.4, a potential positive feedback to winter cooling due to higher albedo.

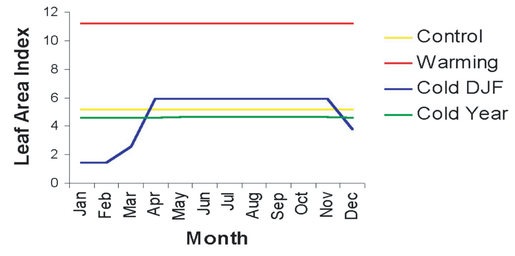

Figure 2. Annual leaf area index for each scenario

Conclusions

Climate change and thermohaline circulation collapse could have significant impacts on ecosystem structure and function.

Some ecosystem responses, (e.g., LAI) constitute positive feedbacks to the climate system.

Accurate projection of ecosystem responses to THC collapse requires better resolution of the seasonal cycle.

Acknowledgements

We thank the Global Change Education Program for generous intellectual and financial support. Jon Foley provided the code for IBIS. Karen McLaughlin provided much needed technical help.